slot auction in which a firm won a noon National Airport slot and two O'Hare slots at 1:30. That firm would be charged a fee based upon our rules for the auction. However, there would be no way to allocate that fee among the three purchased slots. One could not say "the noon National slot cost X dollars." Equally as seriously, that firm (nor any other firm, for that matter) would have no sense of "market price" to guide it on future bidding. These drawbacks have the potential for being fatal, but the auction has never been tested.

Rassenti et al. took a different approach than Forsythe and Isaac. They stuck with trying to develop a market price signal for each commodity which could be tied at least to some degree to the "highest losing bid." They sacrificed the absolute theoretical demand revelation properties that interested Forsythe and Isaac. Instead, they relied upon a "smart" computerized mathematical programming algorithm to choose price and send an approximately "competitive" market signal (a kind of shadow price) for each good. Their bidding algorithm has been tested in the economics laboratory, where it has performed well. Actually, the most sophisticated versions of their "smart markets" computer algorithms have been in difficult network problems (such as markets for electric power or natural gas networks).

D. The FCC Proposal.

In light of the discussion above, what can be said about the FCC's proposed combinatorial auctions? There are four obvious points to make. First, the FCC's proposal (despite some ambiguous language) *is* a combinatorial auction. Imagine a world of three distinct geographic blocks. Suppose, simply for expositional purposes, that *all* four auctions were conducted as sealed bid auctions. Then each bidder could be envisioned as submitting four bids: b_1, b_2, b_3, and b_N (that is, one bid on each of the individual blocks and one bid on the "national" block). Notice that this allows bidders to reveal a certain amount of combinatorial value. Letting B_x represent the winning bid in an auction, the FCC's combinatorial award rule is, correctly:

sell the individual blocks if $B_1 + B_2 + B_3 > B_N$

sell the nationwide license if $B_1 + B_2 + B_3 < B_N$.

Second, the FCC's proposal represents an *incomplete* combinatorial auction. To see this, let's return to the three block example. A complete combinatorial auction would allow bidders to submit bids not just on 1,2,3, and N, but also upon the block s of 1+2, 2+3, and 1+3. The auctioneer, possibly a computer program such as has been developed at the University of Arizona, would put together the *package* of highest bids. Thus the difference with the FCC proposal is that in a complete combinatorial auction the revenue-maximizing allocation could contain some partial aggregation (1, 2+3 for example). With the FCC plan, it is still all or nothing, and some of the disadvantages of non-combinatorial bidding remain. The FCC's proposal has, on the other hand, a significant advantage: it is simple and easy to understand. Combinatorial auctions are not well known. The fact that the example used here uses only three blocs illustrates the fact that the mathematics of the complete combinatorial bidding gets very complicated very quickly. Complexity in this context raises a number of concerns, including difficult and controversial implementation, difficulty in formulating bids, discouraging of potential (especially smaller) bidders, and potentially less efficient outcomes. The FCC's proposal is a simple but appropriate and important first step to introducing and evaluating combinatorial auctions in this process.

Third, the FCC's proposal has some non-standard features. Different parts of the limited combinatorial auction are conducted with two different auction processes: English and sealed bid (Notice at ¶ 47). It is somewhat ambiguous from the Notice whether the sealed bid auction for the group blocks is necessarily first price or could be conducted as a second price auction. Again, the first price auction maintains the standard incentives to mis-reveal value (shave bids). However, as discussed above, second-price rules for combinatorial auctions are not well defined.

An important *potential* problem from mixing the two types of auctions in the limited combinatorial process would be sequencing information spillovers: alterations occurring from the outcomes of the English auction becoming known before the sealed bid auction, or vice-versa.

The FCC has anticipated this concern and has scheduled the auctions to be informationally simultaneous; the sealed bid auction is held first, but the results are not announced until the English auctions are over (Notice at ¶¶ 47, 59, 120). The actual effects on predicted behavior if this simultaneity is lost would require further study.

Fourth, the FCC asks for comments on a "final and best" round in which winners of the first-round bidding for the individual licenses would, if they "lost" the items to an aggregate sealed bid, be given one last chance to recapture the items. (Notice at ¶ 60). Although this seems as though it is simply extending the auction one more round, perhaps to improve the chances of obtaining maximum value revelation (recall the highest-value problem in English auctions discussed above), the incentives of this process are potentially dramatically different. Imagine that such a "final and best" round is underway. Perhaps, using our three-license example from above, the three individual winning bids were 20, 30, and 40 (totalling 90) while the winning bid from the sealed bid auction was 140. Now, each individual license winner is told to submit, in a sealed bid, a new, higher bid. If the final round individual bids beat 140, all of the individual license bidders win. If not, the sealed bid winner takes them as a group. But these bidders do *not* face a standard bidding problem because they are not bidding only to keep their one license. Instead, these bidders, as a group, face a public goods "assurance" problem, with the standard incentives to try to let the other pay for the good (in this case, to provide the 50 needed to switch the outcome).[3] By itself, this suggests a strong possibility that the "final and best" round would be a non-starter.

One standard approach to solving this type of public goods problem would be to allow the individual license winners facing a "final and best" round to communicate with one another. Their task would be to coordinate a plan to come up with bids whose increase totals 50.

[3] See Isaac, Mark R., D. Schmidtz, and J. M. Walker, "The Assurance Problem in a Laboratory Market," *Public Choice*, 62:217-236, 1989.

However, such communication would likely provide the government with very little additional revenue, because the individual license winners described above would seek to exceed the sealed bid by *only* 51 to 50.

The net analytical evaluation of this "final and best" round is at best ambiguous. Furthermore, there is little or no field or experimental evidence to go beyond this theoretical ambiguity.

An alternative approach to dealing with the potential problems of a "final and best" round is to replace it with the elimination of the simultaneity of the English and sealed bid rounds. Specifically, the sealed bid auction for the more aggregated license would be held first, and the results announced. The English auctions for the disaggregated licenses would follow. The preannounced winning bid from the aggregated license *almost* serves the function of simply a preannounced reservation bid. However, it is not *actually* a reservation price in the usual sense because it is a bid going across *all* the English auctions. No actual reservation limit can be assigned to any one disaggregated auction.

Opposing suggestions have been made with regard to the potential effect on bidding activity of preannouncing the aggregated license winning bid. The Notice states that if it becomes clear as the English auctions progress that the aggregated license bid is likely to prevail, then bidding in the English auctions could become dormant (Notice at ¶ 59). However, it is equally possible that if the opposite occurs, namely that the aggregate license bid looks "low", that this would attract *more* bidders to the English auctions.[4] Moreover, even if a "high" combinatory bid causes bidding at the individual auction level to cease, this will provide the additional benefit of substantially expediting the auction process.

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[4] Notice that either argument regarding the proposed preannouncement alternative policy requires some model as to why bidders decide to enter or exit particular auctions.

IV. SUMMARY AND CONCLUSION

Three points can summarize this evaluation of the core FCC proposals. First, the use of competitive bidding to allocate an important national resource is a major policy reform which promises increased efficiency in the use of public resources and, as an incidental benefit, revenue for the federal government. In a very short period of time, the FCC has grasped the fundamental structure of auction theory in general together with the practical requirements of a spectrum auction to put together a credible proposal. Secondly, to be more specific, the FCC's proposed adoption of the English auction as the basic process and the proposal to institute a *limited* combinatorial feature are reasonable. These proposals are consistent with the economic theory and empirical data on auction design and with the practical context as outlined by the FCC. Third, however, there is less theoretical or empirical basis to recommend the "final and best" recontracting proposal. Indeed, there are theoretical reasons to be skeptical.

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